Submitted: 05 August, 2021 Accepted: 25 October, 2021 Published: 08 May, 2022 DOI:10.22514/sv.2021.236

Open Access

Signa Vitae

ORIGINAL RESEARCH

Emergency department crowdedness and emergency department cardiac arrest occurrence: an observational study in the COVID-19 pandemic

Yan-Bo Huang[1,†], Su-Yu Li[2,†], Shang-Kai Hung[1], Li-Heng Tsai[1], Chip-Jin Ng[1], Shou-Yen Chen[1,3,*]

[1]Department of Emergency Medicine, Chang Gung Memorial Hospital and Chang Gung University, 333423 Taoyuan, Taiwan
[2]Department of Nursing, Chang Gung Memorial Hospital, 333423 Taoyuan, Taiwan
[3]Graduate Institute of Clinical Medical Sciences; Division of Medical Education, College of Medicine, Chang Gung University, 333323 Taoyuan, Taiwan

***Correspondence**
allendream0621@yahoo.com.tw; allendream0621@gmail.com; 8902007@cgmh.org.tw
(Shou-Yen Chen)

† These authors contributed equally.

Abstract

Emergency department (ED) crowdedness is a global phenomenon that can lead to many adverse effects. The relationship of crowdedness and emergency department cardiac arrest (EDCA) occurrence is still debated. The COVID-19 pandemic precipitated a change in the patient volume of the ED and the crowdedness of the ED varied with the epidemic in a continuous period. Different degrees of crowdedness provided us with an opportunity to study the relationship between crowdedness and EDCA occurrence. Our aim of this study was to determine the relationship between EDCA occurrence and prognosis and ED crowdedness.This was a longitudinal study conducted in a tertiary teaching hospital. The study period was from October 1, 2019, to September 30, 2020, and was divided into three periods according to daily patient volume and crowdedness. All nontraumatic and adult EDCA patients during the study period were included, and out-of-hospital cardiac arrest (OHCA) patients and patients with do-not-resuscitate orders were excluded.During the study period, a total of 126 EDCA patients were included. The ratio of EDCA events to daily patient volume was compared among these 3 periods, and there was no significant difference (P2: p = 0.109, P3: p = 0.761, P1 as reference). No significant difference in the prognosis of EDCA patients was found among the 3 periods, regardless of the return of spontaneous circulation (ROSC) (p = 0.437) or survival rates (p = 0.838). In conclusion, there was no obvious correlation between ED crowdedness and EDCA occurrence. The prognosis of EDCA patients was not significantly associated with crowdedness. The metrics of ED overcrowding is unknown and may need further study to develop a generally accepted standard or index.

Keywords

EDCA; Cardiac arrest; Crowdedness; Overcrowding

1. Introduction

Increased patient volume and crowdedness at the emergency department (ED) are global phenomena in past decades [1]. ED overcrowding is common in Taiwan because of the National Health Insurance and medical accessibility. This phenomenon could lead to many adverse effects, including higher stress of ED staff, increased frequency of incorrect or contraindicated medications, delayed antibiotic therapy, and elevated mortality in critically ill patients [2–6].

In-hospital cardiac arrest (IHCA) is a critical situation and higher mortality rates were noted in patients with IHCA episodes than patients without IHCA episodes [7]. The proportion of emergency department cardiac arrest (EDCA) is approximately 9–11% among IHCA patients [8]. EDCA patients may have different characteristics from other IHCA patients in the wards or ICUs, and more studies focused on EDCA patients have been conducted in recent years [9]. The prediction of EDCA occurrence and prognosis by scoring systems or machine learning facilitated detection of patients with higher risk of cardiac arrest, and the application of ultrasound or airway management assisted physicians to treat EDCA patients more accurately [10–14]. However, crowdedness is a unique problem for EDCA patients, which makes these patients differ from other IHCA patients. The medical behaviors of physicians may change in an overcrowding environment, and a variety of adverse moral consequences including delays in providing needed care, compromised privacy and confidentiality, impaired communication, and diminished access to care could happen [15]. Previous research has shown diverse results regarding the relation between overcrowding and EDCA occurrence [16, 17]. The relation of crowdedness and EDCA occurrence is still debated. In addition, the medical behaviors of physicains and the prognosis of EDCA patients in EDs with different degrees of crowdedness were not found in previous research.

The COVID-19 pandemic has changed global health systems. The patient volume in EDs changed due to the epidemic in Taiwan [18]. Decreased patient volume and ED crowdedness was noted during COVID-19 pandemic due to fear of getting infected and the policy of quarantine.This significant difference in patient volume over different periods provided us with an excellent opportunity to study the relationship between crowdedness and EDCA in a continuous period with similar members, facilities, and medical conditions. The aim of this study was to determine the relationship between crowdedness and the occurrence, prognosis, and other characteristics of EDCA patients.

2. Material and methods

2.1 Study design

This was a longitudinal study conducted at a university-affiliated tertiary teaching hospital in Taiwan with a 3600-bed capacity and an estimated annual ED volume of 180,000 patient visits. The study was approved by our institutional review board (IRB number 201901062B0). This work was funded by the Chang-Gung Memorial Hospital (CMRPG3J1221).

2.2 Study setting and population

This study was conducted in an emergency department composed of a medical ED, trauma ED, and pediatric ED. Non-traumatic adult patients (age ≥18 years) visited the medical ED with an estimated 108,000 annual patient visits. There were 44 attending physicians, 28 residents and 219 nurses with an advanced cardiovascular life support (ACLS) certificate working in the medical EDs in 2019.

The study period ran from October 1, 2019, to September 30, 2020. The study time was further divided into three periods according to patient volume, which was affected by the COVID-19 epidemic. The first patient with COVID-19 in Taiwan was confirmed on January 11, 2020. The pre-epidemic period (P1) was defined as the period from October 1, 2019, to January 31, 2020. The epidemic period (P2) was defined as the period from February 01, 2020, to April 30, 2020, because the last local case was diagnosed on April 12, 2020, before the new epidemic in 2021 in Taiwan. The wash-out effect was considered to take place in P2. The late epidemic period (P3) was defined as the period from May 01, 2020, to September 30, 2020. Data from patients visiting our ED during the study period were extracted from the electronic medical record system of the hospital. We analyzed the registry data of all consecutive, nontraumatic adult EDCA patients during the study period. Out-of-hospital cardiac arrest (OHCA) patients and patients with do-not-resuscitate orders were excluded.

Data representing crowdedness, such as daily patient volume, patient volume of each shift, number of patients staying in the ED, number of patients waiting for admission and number of patients staying in the ED for more than 48 hours, were all recorded. Characteristics of EDCA patients, such as age, sex, triage acuity level, vital signs, and diagnosis, were collected with a designed form. Medical behaviors that represented the awareness of physicians and nurses of high-risk patients, such as the use of monitoring and the last time vital signs were checked before EDCA, were also recorded.

2.3 Outcome measures

The primary outcome was EDCA occurrence between different periods. Characteristics, diagnosis, medical behaviors, like use of monitor and the time of checking vital signs, and prognosis, such as return of spontaneous circulation (ROSC) and the survival rate in these periods, were also compared and analyzed.

2.4 Statistical analysis

The data were analyzed using SPSS software (version 13.0 for Windows; SPSS, Chicago, IL, USA). Categorical variables are presented as numbers and percentages. The occurrence of EDCA was modeled using Poisson distribution as it is the occurrence of a rare event in a given period of time or for every certain amount of patient visits. The EDCA data was presented in non-negative integral form and different EDCAs are taken to be independent events. The demographics and characteristics were analyzed using one-way ANOVA for continuous variables and Pearson's chi-square test or Fisher's exact test for categorical variables. A p value < 0.05 was considered to be statistically significant.

3. Results

During the study period (October 1, 2019–September 30, 2020), a total of 92,763 emergency room visits were recorded; 126 EDCA patients were included. The average daily ED volume was the highest in P1 (299.25/day) and the lowest in P2 (207.78/day) (Table 1). The average daily EDCA occurrence was 0.37, 0.37, and 0.28 in P1, P2, and P3, respectively, without significance (P2: p = 0.992, P3: p = 0.216, P1 as reference). The ratio of EDCA events to visited patients was also compared among these 3 periods, and the ratio increased in P2 and P3 comparing to P1 without significance (P2: p = 0.109, P3: p = 0.761, P1 as reference). The trends of daily ED volume and number of EDCA events are shown in Fig. 1.

Table 2 demonstrates different indicators of ED crowdedness at EDCA event occurrence in different periods. Patient volume of the day and of the shift reflected the number of new patient that physcians needed to approach. Patient amount at ED and observation room meant the patient number that ED staff had to care at that time. Patient amount waiting admission and staying more than 48 hours revealed the condition of stasis. These five indicators (patient volume of the day, patient volume of the shift, number of patients at the ED, number of patients waiting for admission, and number of patients staying at the ED for more than 48 hours) revealed consistent results. P1 was the most crowded period, and P2 was the least crowded period ($p < 0.001$). The correlation analysis between ED daily volume and EDCA occurrence was done and the association was not significant in any single period (–0.304 in P1 (p = 0.706) , –0.067 in P2 (p = 0.532), and 0.08 in P3 (p = 0.328)) or overall period (r = –0.066, p = 0.206).

The characteristics of EDCA patients were compared among the different periods (Table 3). There were no significant

TABLE 1. Patient volume and EDCA occurrence.

	P1	P2	P3	*p* value
ED volume/day	299.25 ± 37.68	207.78 ± 42.60	245.26 ± 25.41	$p < 0.001$*
EDCA event/day	0.37 ± 0.60	0.37 ± 0.68	0.28 ± 0.48	P2: $p = 0.992$
				P3: $p = 0.216$
				(P1 as reference)
EDCA event/ED volume	0.001358	0.001764	0.001542	P2: $p = 0.109$
				P3: $p = 0.761$
				(P1 as reference)

ED, emergency department; EDCA, emergency department cardiac arrest.

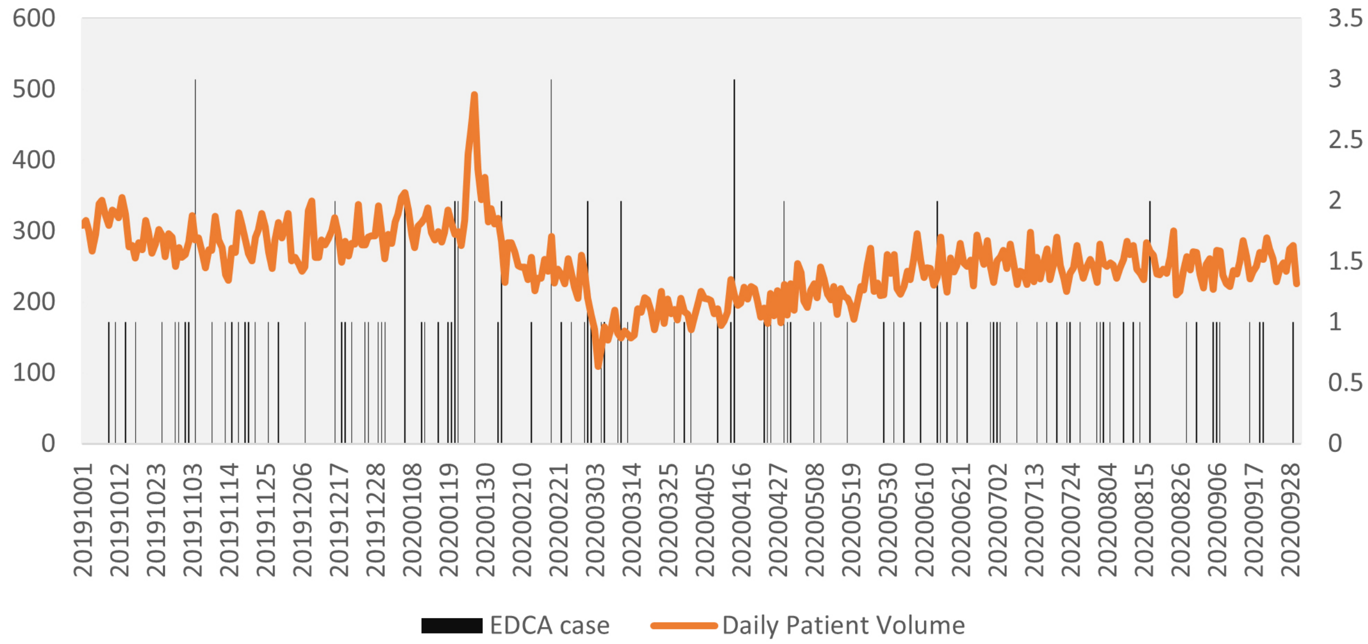

FIGURE 1. EDCA (emergency department cardiac arrest) occurrence and daily ED patient volume.

TABLE 2. ED Crowdedness at EDCA event.

	P1	P2	P3	
Patient volume of the day	482.42 ± 63.25	271.00 ± 64.32	371.49 ± 36.22	$p < 0.001$*
Patient volume of the shift	167.64 ± 43.44	99.55 ± 36.72	124.95 ± 35.21	$p < 0.001$*
Patient amount at ED	166.24 ± 34.24	105.33 ± 24.27	115.72 ± 26.59	$p < 0.001$*
Patient amount waiting admission	131.12 ± 37.21	80.85 ± 17.49	87.60 ± 24.53	$p < 0.001$*
Patient amount staying more than 48 hours	39.84 ± 16.33	23.03 ± 15.48	17.70 ± 7.89	$p < 0.001$*

ED, emergency department; EDCA, emergency department cardiac arrest.

differences in sex ($p = 0.186$), age ($p = 0.798$), or triage level ($p = 0.771$). No significant difference existed in triage vital signs except body temperature ($p = 0.029$). There were no significant differences in the percentage of monitor use ($p = 0.316$) or the last time vital signs were checked ($p = 0.101$) among the different periods. Table 4 shows the prognosis of EDCA patients in the 3 periods. The prognosis of EDCA patients was better in P1 than P2 or P3, but no significant differences were found, either ROSC ($p = 0.437$) or survival rates ($p = 0.838$).

4. Discussion

Research on IHCA began early, and EDCA was included in IHCA in this early stage. However, the characteristics of EDCA patients were quite different from those of IHCA patients in wards or ICUs [9]. Patients in the ED may not be observed as thoroughly and may not have adequate time to receive treatment. Another important difference of EDs from inpatient hospital wards is that patient volume may exceed the limit of facility and manpower in a short time, which could affect the medical quality. Thus, crowdedness is a unique

TABLE 3. Characteristics of EDCA and total ED patients.

	EDCA patients				Total ED patients			
	P1 (N = 50)	P2 (N = 33)	P3 (N = 43)		P1 (N = 35975)	P2 (N = 18338)	P3 (N = 36618)	
Sex, male (%)	37 (74.00%)	18 (54.55%)	28 (65.12%)	$p = 0.186$	17950 (49.89%)	9477 (51.67%)	18626 (50.86%)	$p < 0.001$
Age, years	68.52 ± 14.22	67.70 ± 15.42	66.44 ± 15.29	$p = 0.798$	54.53 ± 19.47	53.89 ± 19.61	55.31 ± 19.32	$p < 0.001$
Triage level (%)				$p = 0.771$				$p < 0.001$
I	16 (32%)	9 (27.3%)	174 (0.0%)		1306 (3.63%)	747 (4.07%)	1411 (3.85%)	
II	22 (44%)	16 (48.5%)	15 (34.9%)		4712 (13.09%)	2597 (14.1%)	4976 (13.58%)	
III	12 (24%)	8 (24.2%)	11 (25.6%)		27515 (76.48%)	13042 (71.12%)	28233 (77.10%)	
IV					2293 (6.37%)	1754 (9.56%)	1864 (5.09%)	
V					148 (0.41%)	197 (1.07%)	130 (0.69%)	
Triage vital signs								
Temperature (°C)	36.42 ± 1.19	35.98 ± 1.42	36.79 ± 1.33	$p = 0.029$*	36.58 ± 1.08	36.72 ± 1.10	36.83 ± 0.98	$p < 0.001$
Heart rate (beat per minute)	100.24 ± 31.12	95.27 ± 30.26	100.53 ± 30.54	$p = 0.714$	92.00 ± 20.33	93.71 ± 20.77	90.38 ± 20.20	$p < 0.001$
Respiratory rate (time per minute)	22.37 ± 8.28	24.41 ± 7.68	22.19 ± 6.32	$p = 0.387$	18.23 ± 3.01	18.30 ± 2.95	18.36 ± 2.84	$p < 0.001$
Systolic blood pressure (mmHg)	105.20 ± 42.12	108.91 ± 31.42	101.28 ± 50.89	$p = 0.743$	138.35 ± 29.60	142.43 ± 30.64	139.57 ± 29.95	$p < 0.001$
Medical behaviors								
Monitor use (%)	42 (84.00%)	24 (72.73%)	31 (72.09%)	$p = 0.316$				
Last checked time of vital signs before EDCA (minutes)	84.76 ± 103.34	49.97 ± 93.45	48.60 ± 68.06	$p = 0.101$				
Cardiogenic cause (%)	12 (24%)	9 (27.3%)	5 (11.6%)	$p = 0.186$				
Initial Rhythm				$p = 0.359$				
VT/VF (%)	4 (8%)	4 (12.1%)	3 (7%)					
PEA (%)	34 (68%)	23 (69.7%)	36 (83.7%)					
Asystole (%)	12 (24%)	6 (18.2%)	4 (9.3%)					

ED, emergency department; EDCA, emergency department cardiac arrest; VT, ventricular tachycardia; VF, ventricular fibrillation; PEA, pulseless electrical activity.

TABLE 4. Prognosis of EDCA patients.

	P1 (N = 50)	P2 (N = 33)	P3 (N = 43)	
ROSC (%)	31 (62%)	19 (57.6%)	21 (48.8%)	$p = 0.437$
Survival (%)	24 (48%)	15 (45.5%)	18 (41.9%)	$p = 0.838$

EDCA, emergency department cardiac arrest; ROSC, return of spontaneous circulation.

problem in the ED. For the above reasons, EDCA was separated from IHCA and studied as an independent group in recent years [10–12, 16, 17, 19]. Our study focused on the relationship between EDCA patients and degree of ED crowdedness, and revealed that EDCA event coccurence was not associated to crowdedness. There was no difference of medical behaviors such as monitor use and the time interval of checking vital signs in different crowdedness. ROSC and survival rates of EDCA patients were slightly higher in the crowding period without significance.

Crowdedness was assumed to affect medical quality and possibly be associated with EDCA occurrence, but the results of research showed diverse results. Chang et al reported that high ED crowdedness increased the EDCA incidence [16]. In this study, the ED bed occupancy rate (EDBOR) was used as an overcrowding index by calculating the ratio of the total number of filled beds divided by the total number of licensed ED beds. However, a different result was found in another similar study using the same index of EDBOR [20]. One possible explanation is that EDBOR might not reflect the proportion of critically ill patients. Another reason is that crowdedness could be dynamic and changes rapidly, so EDBOR may not be calculated as a real-time index. Although these previous studies suggested some parameters that reflect ED crowdedness, no single universally accepted or standardized measure of ED crowdedness existed [21]. The same parameter could represent diverse conditions in different hospitals or countries.

The COVID-19 epidemic began in 2019. Although the epidemic was well controlled in Taiwan in 2020, it still influenced health systems and hospitals [22, 23]. The patient volume of EDs significantly decreased in the epidemic period due to quarantine policies and fear of becoming infected with COVID-19 [18]. This continuous period showed different degrees of ED crowding without obvious changes in patient characteristics or ED staff composition. No significant difference in EDCA occurrence was found to be associated with crowdedness in our study. A possible explanation is that the crowdedness of our study periods did not achieve “overcrowding”. Without achieving the degree of overcrowding, EDCA occurrence is not significantly associated with crowdedness.

The occurrence of IHCA/EDCA, in many cases, could be considered preventable in some research since clinical deterioration may be observed prior to cardiac arrest [24, 25]. For example, Pediatric Early Warning Scores (PEWS) were used in pediatric hospitalised patients to detect physiological deterioration, but most evidence has come from research based on paediatric inpatients in specialist children’s hospitals, but the evidence of using this score at ED was still limited [26, 27]. No standard predictive model has sufficient sensitivity and specificity to identify high-risk patients in the beginning at ED [28]. Close observation and monitoring of high-risk patients may be the most useful method to prevent cardiac arrest events [7]. In our study, monitor use in high risk patients and obtaining frequent vital signs could be useful methods to prevent EDCA occurrence. The percentage of monitor use and frequency of checking vital signs were not different among the periods, which means that the awareness of physicians and nurses remained the same and was not affected by crowdedness. This could be another reason why there was no difference in EDCA occurrence among the three periods. Crowdedness was not high enough to negatively affect the attention and quality of care in the study.

There are known factors associated with clinical outcomes of IHCA patients; for example, presenting rhythm and cardiogenic cause are associated with increased survival [29, 30]. Early initiation of CPR and good quality chest compressions are also associated with better outcomes for IHCA patients [31, 32]. In our study, the prognosis of EDCA patients was shown to be uncorrelated to ED crowding in our study, regardless of the ROSC or survival rate. The early detection of cardiac arrest occurrence, immediate resuscitation, and adequate experience among medical personnel performing CPR despite the degree of crowdedness at the ED were possible reasons [17, 31, 32]. Similar results were reported in a previous study of OHCA patients [33]. This study, conducted by Kang *et al.* [33], found that ED overcrowding was not associated with the prognosis of OHCA or the quality of CPR.

Another finding was that EDCA occurrence was slightly elevated in the early epidemic period (P2) for a short time. This may be attributed to newly implemented policies for the COVID-19 epidemic, including the use of personal protective equipment and the establishment of quarantine areas [34, 35]. These new changes may have caused obstacles in treating patients immediately and smoothly compared to normal conditions.

5. Limitations

This study has several limitations. First, this study was conducted in a single hospital in one country, and selection bias existed and influenced the results. Second, our research was performed in a medical center and may not reflect the situation in the regional or local hospitals, which have less manpower and facilities and could be more significantly affected by crowdedness. Third, some confounding factors and patient characteristics, such as underlying diseases, pre-existing conditions, patient care given, chief complaints, and treatment, were not included in our analysis. Fourth, several indicators related to ED volume were used to measure crowdedness in our study, but other indicators, such as EDBOR were not adopted, so they may not comprehensively reflect crowdedness. Finally, the crowdedness of our study periods may not achieve “overcrowding” and crowdedness was not high enough to negatively affect the attention and quality of care in the study. Without achieving the degree of overcrowding, the results of our study may not reflect the relationship between EDCA occurrence and ED crowdedness completely.

6. Conclusions

Our study findings suggest no statistically significant association between ED crowdedness and EDCA occurrence during the COVID-19 pandemic. It is necessary, however, to further evaluate a means of comprehensively measuring ED crowdedness and its effects on the delivery of patient care. The standard and metrics of ED overcrowding are unknown and may need further study to develop a generally accepted standard or index.

AUTHOR CONTRIBUTIONS

Conceptualization—YBH, SYL and SYC; Data curation—YBH, SYL and SKH; Formal analysis—YBH, LHT and SYC; Figure preparation—YBH and SYL; Investigation—YBH, SYL, SKH and SYC; Writing-original draft—YBH and SYL; Writing-review&editing—SYC and CJN. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Chang Gung Medical Foundation Institutional Review Board approved this study (IRB number: 201901062B0).

ACKNOWLEDGMENT

We are thankful to our colleagues who provided their expertise, which greatly assisted the research, although they may not agree with all the interpretations provided in this paper.

FUNDING

This work was funded by the Chang-Gung Memorial Hospital (CMRPG3J1221).

CONFLICT OF INTEREST

The authors declare no conflict of interest. Shou-Yen Chen is serving as one of the Guest editors of this journal. We declare that Shou-Yen Chen had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to SOH.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

REFERENCES

[1] Pines JM, Hilton JA, Weber EJ, Alkemade AJ, Al Shabanah H, Anderson PD, *et al*. International perspectives on emergency department crowding. Academic Emergency Medicine. 2011; 18: 1358–1370.

[2] Morley C, Unwin M, Peterson GM, Stankovich J, Kinsman L. Emergency department crowding: A systematic review of causes, consequences and solutions. PLoS ONE. 2018; 13: e0203316.

[3] Bond K, Ospina MB, Blitz S, Afilalo M, Campbell SG, Bullard M, *et al*. Frequency, determinants and impact of overcrowding in emergency departments in Canada: a national survey. Healthcare Quarterly. 2007; 10: 32–40.

[4] Kulstad EB, Sikka R, Sweis RT, Kelley KM, Rzechula KH. ED overcrowding is associated with an increased frequency of medication errors. The American Journal of Emergency Medicine. 2010; 28: 304–309.

[5] Gaieski DF, Agarwal AK, Mikkelsen ME, Drumheller B, Cham Sante S, Shofer FS, *et al*. The impact of ED crowding on early interventions and mortality in patients with severe sepsis. The American Journal of Emergency Medicine. 2017; 35: 953–960.

[6] Jo S, Jeong T, Jin YH, Lee JB, Yoon J, Park B. ED crowding is associated with inpatient mortality among critically ill patients admitted via the ED: post hoc analysis from a retrospective study. The American Journal of Emergency Medicine. 2015; 33: 1725–1731.

[7] Andersen LW, Holmberg MJ, Berg KM, Donnino MW, Granfeldt A. In-Hospital Cardiac Arrest: A Review. JAMA: Journal of the American Medical Association. 2019; 321: 1200–1210.

[8] Donoghue AJ, Abella BS, Merchant R, Praestgaard A, Topjian A, Berg R, *et al*. Cardiopulmonary resuscitation for in-hospital events in the emergency department: A comparison of adult and pediatric outcomes and care processes. Resuscitation. 2015; 92: 94–100.

[9] Kayser RG, Ornato JP, Peberdy MA. Cardiac arrest in the Emergency Department: a report from the National Registry of Cardiopulmonary Resuscitation. Resuscitation. 2008; 78: 151–160.

[10] Jang DH, Kim J, Jo YH, Lee JH, Hwang JE, Park SM, *et al*. Developing neural network models for early detection of cardiac arrest in emergency department. The American Journal of Emergency Medicine. 2020; 38: 43–49.

[11] Mitchell OJL, Edelson DP, Abella BS. Predicting cardiac arrest in the emergency department. Journal of the American College of Emergency Physicians Open. 2020; 1: 321–326.

[12] Hong S, Lee S, Lee J, Cha WC, Kim K. Prediction of Cardiac Arrest in the Emergency Department Based on Machine Learning and Sequential Characteristics: Model Development and Retrospective Clinical Validation Study. Journal of Medical Internet Research. 2020; 8: e15932.

[13] Long B, Alerhand S, Maliel K, Koyfman A. Echocardiography in cardiac arrest: an emergency medicine review. The American Journal of Emergency Medicine. 2018; 36: 488–493.

[14] Pokrajac N, Sbiroli E, Hollenbach KA, Kohn MA, Contreras E, Murray M. Risk Factors for Peri-intubation Cardiac Arrest in a Pediatric Emergency Department. Pediatric Emergency Care. 2020. (in press)

[15] Moskop JC, Sklar DP, Geiderman JM, Schears RM, Bookman KJ. Emergency department crowding, part 1–concept, causes, and moral consequences. Annals of Emergency Medicine. 2009; 53: 605–611.

[16] Chang YH, Shih HM, Chen CY, Chen WK, Huang FW, Muo CH. Association of sudden in-hospital cardiac arrest with emergency department crowding. Resuscitation. 2019; 138: 106–109.

[17] Kim JS, Bae HJ, Sohn CH, Cho SE, Hwang J, Kim WY, *et al*. Maximum emergency department overcrowding is correlated with occurrence of unexpected cardiac arrest. Critical Care. 2020; 24: 305.

[18] Lo HY, Chaou CH, Chang YC, Ng CJ, Chen SY. Prediction of emergency department volume and severity during a novel virus pandemic: Experience from the COVID-19 pandemic. The American Journal of Emergency Medicine. 2021; 46: 303–309.

[19] Kim JS, Seo DW, Kim YJ, Jeong J, Kang H, Han KS, *et al*. Prolonged Length of Stay in the Emergency Department and Increased Risk of In-Hospital Cardiac Arrest: A nationwide Population-Based Study in South Korea, 2016–2017. Journal of Clinical Medicine. 2020; 9: 2284.

[20] Ye S, Liu JZ, He YR, Cao Y. Emergency department crowding might not strongly associated with higher incidence of in-hospital cardiac arrest. Resuscitation. 2019; 140: 72–73.

[21] Hwang U, McCarthy ML, Aronsky D, Asplin B, Crane PW, Craven CK, *et al*. Measures of crowding in the emergency department: a systematic review. Academic Emergency Medicine. 2011; 18: 527–538.

[22] Cheng HY, Jian SW, Liu DP, Ng TC, Huang WT, Lin HH, *et al*. Contact Tracing Assessment of COVID-19 Transmission Dynamics in Taiwan

and Risk at Different Exposure Periods before and after Symptom Onset. JAMA Internal Medicine. 2020; 180: 1156–1163.
[23] Steinbrook R. Contact Tracing, Testing, and Control of COVID-19-Learning From Taiwan. JAMA Internal Medicine. 2020; 180: 1163–1164.
[24] Galhotra S, DeVita MA, Simmons RL, Dew MA. Mature rapid response system and potentially avoidable cardiopulmonary arrests in hospital. Quality & Safety in Health Care. 2007; 16: 260–265.
[25] Andersen LW, Kim WY, Chase M, Berg KM, Mortensen SJ, Moskowitz A, *et al*. The prevalence and significance of abnormal vital signs prior to in-hospital cardiac arrest. Resuscitation. 2016; 98: 112–117.
[26] Chapman SM, Maconochie IK. Early warning scores in paediatrics: an overview. Archives of Disease in Childhood. 2019; 104: 395–399.
[27] Duncan H, Hutchison J, Parshuram CS. The Pediatric Early Warning System score: a severity of illness score to predict urgent medical need in hospitalized children. Journal of Critical Care. 2006; 21: 271–278.
[28] Smith ME, Chiovaro JC, O'Neil M, Kansagara D, Quiñones AR, Freeman M, *et al*. Early warning system scores for clinical deterioration in hospitalized patients: a systematic review. Annals of the American Thoracic Society. 2014; 11: 1454–1465.
[29] Chan PS, Spertus JA, Krumholz HM, Berg RA, Li Y, Sasson C, *et al*. A validated prediction tool for initial survivors of in-hospital cardiac arrest. Archives of Internal Medicine. 2012; 172: 947–953.
[30] Harrison DA, Patel K, Nixon E, Soar J, Smith GB, Gwinnutt C, *et al*. Development and validation of risk models to predict outcomes following in-hospital cardiac arrest attended by a hospital-based resuscitation team. Resuscitation. 2014; 85: 993–1000.
[31] Bircher NG, Chan PS, Xu Y. Delays in Cardiopulmonary Resuscitation, Defibrillation, and Epinephrine Administration All Decrease Survival in In-hospital Cardiac Arrest. Anesthesiology. 2019; 130: 414–422.
[32] Wallace SK, Abella BS, Becker LB. Quantifying the effect of cardiopulmonary resuscitation quality on cardiac arrest outcome: a systematic review and meta-analysis. Circulation. Cardiovascular quality and outcomes. 2013; 6: 148–156.
[33] Kang J, Kim J, Jo YH, Kim K, Lee JH, Kim T, *et al*. ED crowding and the outcomes of out-of-hospital cardiac arrest. The American Journal of Emergency Medicine. 2015; 33: 1659–1664.
[34] Montrief T, Ramzy M, Long B, Gottlieb M, Hercz D. COVID-19 respiratory support in the emergency department setting. The American Journal of Emergency Medicine. 2020; 38: 2160–2168.
[35] Chavez S, Long B, Koyfman A, Liang SY. Coronavirus Disease (COVID-19): A primer for emergency physicians. The American Journal of Emergency Medicine. 2021; 44: 220–229.

How to cite this article: Yan-Bo Huang, Su-Yu Li, Shang-Kai Hung, Li-Heng Tsai, Chip-Jin Ng, Shou-Yen Chen. ED crowdedness and EDCA occurrence: an observational study in the COVID-19 pandemic. Signa Vitae. 2022; 18(3): 33-39. doi:10.22514/sv.2021.236.